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by

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COUNTERMEASURES OF MILITARY SPACE SYSTEMS

Tian Bo

ABSTRACT: Countermeasures can effectively ensure the safety of space systems in coping with space challenges in military space systems. Briefly, the article presents the features and difficulties of space system countermeasures, along with the types and attack principles against hostile threats against satellites, protective techniques of satellite-borne systems, selection of countermeasure platforms, countermeasure types, countermeasure techniques with multiple platforms, space C³ countermeasures, space countermeasure techniques, and integration of space countermeasures.

KEY WORDS: space warfare, space conflicts, electronic countermeasures, and anti-satellite defense.

I. INTRODUCTION

In supporting missions by the United States Armed Forces in communication, navigation, reconnaissance, and meteorology, American military satellites (various types of military communication satellites, navigation guidance satellites, various types of reconnaissance satellites, and military meteorological satellites) have exerted important functions. Many technical systems require space systems. Reliance on these military satellite systems by the United States Armed Forces--Army, Navy, and Air Force--is so indispensable that no effective combat can

be waged without these space systems. Military satellites operate high in space above the ground that enemies find it difficult to approach. These satellites provide unique communication links and stay operating for very long periods (for months or years). Of course, these advantages are also accompanied with obvious disadvantages. For example, military satellites are far from the supervisory troop units or from troops required in satellite support. It requires reliance on remote control sensors to have access to data on of the status, operations and performance indicators of the satellite systems so that operators are required. Since space systems are very important to military combat, we should give due consideration on how to protect the system resources in order to prevent enemies from adopting any threat with potential damage to space system safety. In this respect, electronic countermeasures have the key function.

II. Applications of Countermeasures

As indicated by the history of electronic warfare, in combat electronic systems exert more important major functions with more and more proportional involvement of electronic equipment in ordnance systems. Electronic systems control more combat activities and exhibit their unique superiority in applications of the most recent high technology. The meaning of electronic combat (EC) in the United States Air Force is to comprehensively employ various military activities to protect our side and our friends' side to utilize the electromagnetic frequency spectrum, and to weaken or to deprive the enemy from the use of the electromagnetic frequency spectrum, including the electronic combat, C³ countermeasures, as well as suppression against the enemy's air defense systems (SEAD). Under the principle of electronic combat, the application range of space countermeasures may include the following:

1. Protect the space system, similar to the self-protective function of aircraft; and

2. Space C³ countermeasures, including the application of jamming to deal with the enemy's C³ links threatening the safety of our space systems.

III. Protection of Space Systems

Countermeasures are the most commonly used approach. As an integral part of the system, countermeasures can enhance the survivability of the important military space system of the United States. This mission can be considered as the extension of survivability that applies to aircraft.

3.1. Anti-satellite Threat (ASAT)

Since the vast majority of space systems are unmanned satellites operating in space orbits, their positions are known by potential enemies. To these enemies, they can acquire such information as the mission and important purposes of these military satellites: in most situations, even design data on these systems. Therefore, the concept of the feasibility of potential threats against these systems has taken form. According to the position and the destruction regime of these anti-satellite systems, we can classify these potential threats. Generally speaking, anti-satellite threats can be divided into four types: land-based, sea-based (shipborne), air (aircraft-borne), and space (satellite-borne). Table 1 shows the general classification of the destruction regime against satellites.

Combining with the four above-mentioned types of deployment (land-based, shipborne, air-borne, and satellite-borne), the anti-satellite threat systems can be subdivided into 36 subtypes. If consideration is given to the systems concept, the important requirements can be attained against the threats. Thus, in applying the countermeasures concept to protect space systems, designers confront this challenging problem of how to solve the above-mentioned threats.

From the developmental history of electronic countermeasure systems on earth, very few of them are directly against the space

TABLE 1. CLASSIFICATION OF Anti-satellite THREATS

类 别 a		定 义 b
拦截器 c	动能杀伤 f	直接碰撞,摧毁卫星。 o
	常规弹头 g	化学弹药,在使卫星致命的半径范围内爆炸,摧毁卫星。 p
	核弹头 h	核弹药,在使卫星致命的半径范围内爆炸产生核辐射,摧毁卫星。 q
直接能武器 d	高功率射频 i	通过射频电磁辐射,使部件过载或加热使结构损坏,造成电子线路长期故障。 r
	高能激光 j	由于高能激光波束的照射加热,致使结构损坏。 s
	中性粒子波束 k	由于高能中性带电粒子波束的照射,致使结构损坏。 t
电子战威胁 e	高功率射频 l	通过异常耦合使电子线路的正常工作受到暂时干扰。 u
	噪声干扰 m	有意发射电磁干扰噪声,破坏对有关接收机的发射。 v
	欺骗干扰 n	有意发射干扰信号,控制目标系统的活动状态。 w

KEY: a - classification b - definition c - acquisition device
d - direct-energy weapon e - electronic warfare threat
f - kinetic-energy destruction g - conventional warheads
h - nuclear warheads i - high-powered radio frequencies
j - high-energy lasers k - neutral particle beam l - high-power
radio frequency m - noise jamming n - deception jamming
o - destroying the satellite by direct collision p - destroying
the satellite by exploding chemical munitions within the fatal
radius of the satellite q - destroying the satellite by
detonating nuclear bombs within the fatal radius of the satellite
r - with electromagnetic bombardment with radio frequency to
overload or heat up the components to destroy the structure,
causing long-term malfunctioning of electronic circuits
s - damaging the structure by illuminating and heating up with
high-energy laser beams t - damaging the structure with
illumination of high-energy neutral or charged particle beams
u - temporary jamming the ordinary operation of electronic
circuitry by abnormal coupling v - jamming the transmission of
receivers by intentional sending out electromagnetic interference
w - control the activities of target systems by intentionally
emitting interference signals

systems with threats. During the design, the unique features of these threats are often used to jam normal operations. With the variable batch production cycles, countermeasure systems are being continuously upgraded and strengthened, thus attaining the gradual progress together with the threat systems that countermeasures are required to deal with. Through practice

(participation of combat exercises, etc.) as well as the repeated developmental process, many improvements have been gradually realized. With repetitive applications of countermeasures and counter-countermeasures, the time required for each cycle is shorter and shorter, relatively speaking.

A satellite-borne system should operate in space for many years. Actually, the possibilities of approaching these systems are practically nonexistent, or the costs of approach are too high. Therefore, improvement and strengthening of satellite-borne systems are in reality engaged in the next batch production or those required to be replaced. Compared with the aircraft-borne countermeasures system, actually the satellite-borne systems do not provide practical experience for reference by personnel analyzing space countermeasures. As a result, they only can design a satellite-borne system relying on dribs and drabs of understanding of potential enemy anti-satellite systems.

3.2. Combat Principles Against Satellite Threats

Notwithstanding the above mentioned problems, development schemes of countermeasure systems can still be prescribed. There are some common features for all anti-satellite threats; these system threats should include the following combat components in order to exploit the due functions in military combat.

3.2.1. Command and Control

The anti-satellite command organization commands and controls its troops under this function, including monitoring the status of the target satellites and issuing order, such as when to approach the target for combat, or when to leave off contact.

3.2.2. Search

The function includes the search and detection of potential targets in the related regions, as well as other targets in these regions.

3.2.3. Acquisition of Targets

This is to conduct analysis, on the detected targets in the search period, and to discriminate the particular target to be

attacked among many targets.

3.2.4. Tracking of Targets

This is to track the selected target, and to calculate the algorithm to be solved for combat.

3.2.5. Guidance

For the selected weapon to be guided to the final target, based on the system concept, it provides an automatic guidance system (such as the homing head in the missile acquisition device) or another tracking device to send the directional wave beam for guidance.

3.2.6. Conclusions

Attain the effectiveness of finally destroying the target.

Although there are many anti-satellite system structures that can be selected, yet only a few of them can carry out such combat missions. Due to limitations of physical laws and technology, these methods are limited by whether or not combat at a certain point can be waged at the right time. Formation and development of the space countermeasures concept are driven by the continuously emerging threat system, rather than the effect of the anti-satellite threat regime.

3.3. Scheme for Protecting Satellite-borne Systems

Under the concept of applying space countermeasures to protect our satellite-borne systems, the three following protective schemes can be applied singly or in combination.

3.3.1. Reduction of Sensitivity

Adopting such measures aims at lowering the inherent sensitivity of a satellite-borne system against anti-satellite threats (attack). Based on the mission of the satellite-borne system, and the expected threat status, by so doing it will perhaps be sufficient (or insufficient); frequently, tradeoffs are required in lowering the sensitivity and the mission performance. This approach of solving the problem limits to some extent that only the satellite-borne system should be protected.

3.3.2. Countermeasure Reactions to be Acted On

Based on the attack regime of anti-satellite systems, which protection countermeasures should be taken in reaction? In the inherent meaning of this scheme, it is to assume that the corresponding anti-satellite combat elements should be detected and recognized for applying countermeasures.

3.3.3. Countermeasures to be Waged in Advance, or Prearranged Countermeasures Are Readied Before Detecting an Actual Anti-satellite Attack

Generally speaking, very few of these measures can be applied in space systems. Based on the results of monitoring space activities over many years, there is no obvious advantage to applying countermeasures prior to an attack by an anti-satellite system. In this way, more time will be reserved to the potential enemy for monitoring, analyzing, and designing a system that can cope with such countermeasures.

3.4. Countermeasures Structure

There is a series of structures capable of being applied in space countermeasures. These structures are required to be installed on a platform in order to analyze the types of countermeasures to be adopted. In the following, the optimal selection of countermeasures platform is related to the protection of space systems.

3.4.1. Installed on a Single Satellite

The countermeasures equipment and payload for carrying out the mission are installed in a single satellite.

3.4.2. Installed in Another Satellite, But in the Same Orbit

The countermeasures equipment is installed in another satellite operating in the same orbit in order to protect the space system.

3.4.3. Installed in a Remote Satellite

The countermeasures equipment is installed in another satellite operating in a different orbit, whose height, generally speaking, is higher than the orbit of the satellite to be protected.

Table 2 lists the selected platforms and the corresponding advantages and disadvantages.

TABLE 2. OPTIMAL SELECTION OF COUNTERMEASURES PLATFORMS

1 结构	2 优点	3 缺点
同星 4	<ul style="list-style-type: none"> • 对抗概念简单 7 • 每颗卫星都具有可生存能力 8 	<ul style="list-style-type: none"> • 影响卫星负载 15 • 所有要保护的卫星都必须装有对抗设备 16 • 由于总体限制,可实施的干扰反应有限 17
随星 5	<ul style="list-style-type: none"> • 对所保护的卫星没有整体影响 9 • 对对抗设备限制较少 10 	<ul style="list-style-type: none"> • 需要增加卫星 18 • 与星载相比,需要更复杂的执行机构 19 • 所处的几何位置会影响其效果 20 • 对抗卫星可能会成为目标 21
远星 6	<ul style="list-style-type: none"> • 总体上不影响所保护的卫星 11 • 对对抗设备限制较少 12 • 能有效地对付威胁可选择最佳轨道 13 • 能保护更大的区域 14 	<ul style="list-style-type: none"> 需要增加卫星 22 • 与星载和随行相比需要更复杂的执行机构 23 • 对抗卫星可能会成为目标 24

KEY: 1 - structures 2 - advantage 3 - disadvantage 4 - same satellite 5 - another satellite in the same orbit 6 - remote satellite 7 - simple countermeasures concepts 8 - each satellite has feasible survivability 9 - without integrated effect on the protected satellite 10 - fewer limitations on countermeasure equipment 11 - generally, does not affect the protected satellite 12 - fewer limitations on countermeasures equipment 13 - optimal orbit can be selected to effectively cope with threats 14 - can protect greater zone 15 - affect satellite loading 16 - all protected satellites should be equipped with countermeasures equipment 17 - due to overall limitations, there are limited jamming reactions that are feasible 18 - it is required to increase the number of satellites 19 - compared with satellite-borne type, more complicated execution mechanisms should be required 20 - the geometric position will affect the effectiveness 21 - the countermeasures satellite may possibly become a target 22 - the number of satellites should be increased 23 - when a satellite-borne platform is compared with a same-orbit satellite, a more complicated execution mechanism is required 24 - the countermeasures satellite may become a target.

3.5. Electronic Countermeasure Types

The electronic countermeasure types applied to a space system are an extension of the aircraft-borne application types, including noise jamming, deception jamming, and countermeasures outside the satellite.

3.5.1. Noise Jamming

Noise jamming is applied against the communication links of the anti-satellite system.

3.5.2. Deception Jamming

This includes the adoption of active measures to generate deception signals to the anti-satellite systems and components.

1. Action deception: to provide false distance, angle, or velocity information to the space systems to be protected.

2. Activities and missions: sending of the activities, missions, and status (in false information) about the related space systems.

3.5.3. Countermeasures Outside the Satellite

Disperse material from a satellite to provide deception targets to the anti-satellite systems, such as, lures, foils, and flares (requiring the generation of oxygen). Table 3 lists the various components of anti-satellite systems that can have functions and countermeasures against attack.

TABLE 3. COUNTERMEASURES WITH RESPECT TO VARIOUS Anti-satellite SYSTEM COMPONENTS

对抗方式 1	对反卫星系统起作用的部分 2					
	指挥与控制 3	搜索 4	目标获取 5	目标跟踪 6	制导 7	摧毁 8
9 噪声干扰	✓	✓	✓	✓	✓	✓
10 欺骗动作	12	✓	✓	✓	✓	✓
干扰活动任务	13				✓	✓
11 星外诱饵	14	✓	✓	✓	✓	✓
箔条	15			✓	✓	✓
16 曳光弹	16			✓	✓	✓

KEY: 1 - countermeasure types 2 - functioning component of anti-satellite system 3 - command and control 4 - search 5 - target acquisition 6 - tracking of target 7 - guidance 8 - destruction 9 - noise jamming 10 - deception jamming 11 - dispersion outside of satellite 12 - actions 13 - activities and mission 14 - lures 15 - foils 16 - flares

3.6. Technology of Multiple Platforms

Space countermeasures technology can be executed with a single platform or with multiple platforms. Compared with the single-platform technology, multiple-platform technology is superior. Although it is well known that some technologies that can be applied to multiple platforms, yet it is difficult to coordinate these multiple systems with respect to activities and positions, and these technologies are difficult to be applied to aircraft or ships. Since the motion locus and the geometric positions of space systems are known, naturally such multiple-platform countermeasures technologies can be applied. There are the following examples in multiple-platform countermeasures:

1. Wavefront distortion: such wavefront distortion signals are intentionally generated and synthesized; such synthesized wavefronts (signals) are generated from a set of satellites capable of effectively jamming the angle measurement signal processing of anti-satellite threat systems.

2. Phase reference jamming: high-powered jamming signal is sent with respect to the phase correlation of the receiver of the system to be threatened.

3. Utilization of unique features: in a set of satellites, signal features of a satellite are changed, thus disturbing the tracking and discrimination functions of the threat source.

IV. Space C³ Countermeasures

With respect to a potential enemy, its space system is similarly important. The purpose of the space C³ countermeasures is to support the military combat activities by adopting countermeasure actions against the threat space system. The countermeasures space system possibly includes the communication links of a communication satellite, navigation guidance satellite, reconnaissance satellite, or other kind of satellite. As mentioned above, many measures may also be applied in space C³ countermeasures.

The common properties of the space systems are to apply

dedicated communication links for remote measurement, tracking, and command (TT&C) communication. Their functions are to determine the positions of space satellites for tracking, sending of commands, controlling of satellite action, and receiving data sent from sensors and missions systems. Generally speaking, this can be compared to a satellite manager. With respect to the importance of the foregoing functions, special protective measures should be applied to the TT&C links of the satellite system in order to prevent access by other users.

4.1. Communication Satellites

Since the important C³ links are more and more extensively applied to communication satellites, it naturally becomes a clear target for countermeasures. Generally, there are three types of stellar orbits of communication satellites: geostationary orbits (which are synchronized orbits, positioned over the equator at a height of 36,000km), high elliptical orbits (such as the Molniya satellites of the Soviet Union), and low orbits. Generally, these satellite orbits are known. As the power of satellite transponders is limited, these transponders operate in a situation of known parameters for radio frequencies. These transponders should be shared among multiple users in order to maintain the equilibrium according to plan. As for a recent jamming event against television broadcasting to commercial satellites, this illustrates that it is not very difficult to control these transponders. Therefore, other antijamming measures should be adopted for military communication satellites. Confronted with the complicated form of the countermeasures, these military communication satellites are technically limited.

4.2. Navigation Guidance Satellites

Due to the importance of tactical and strategic troop units, naturally navigation guidance satellites become the potential targets of countermeasures. The orbits of navigation guidance satellites include low orbit and pseudosynchronous orbit. As a

navigation guidance satellite is launched, it passes through encoded time coordinates. A dedicated receiver thus can calculate the triangular three-dimensional position. By carrying out countermeasures against such a system, it is mainly the jamming of its launch, or providing a simulated launch to deceive the navigation guidance users.

4.3. Space C³ Countermeasures Systems

To be a useful component of military combat, the space C³ countermeasures system should include the following aspects, with a certain scale.

(1) Mission plan: combine the application of countermeasures and combat battle sites.

(2) Probing of environment: probe electromagnetic frequencies in order to compile an electronic environment, such as a database.

(3) Acquisition of signals by detecting the useful signals.

(4) Signal analysis: categorize, discriminate, and mark large numbers of target signals.

(5) Application of countermeasures: apply specific countermeasure activities against the marked target signals.

(6) Evaluation of effectiveness on the above-mentioned countermeasures results.

V. Space Countermeasures Technology

In order to attain the target for space countermeasures, it is required to have new progress in the following technical fields.

5.1. Detection and Tracking of Threat Sources

To seek appropriate countermeasures, it is required to verify and design the scheme of the satellite-borne threat warning system, which should cover most frequency spectra and cope with various threat approaches. Moreover, the system should employ a verified signal much weaker than the alarming signal of

a conventional radar to analyze and discriminate the threat system.

5.2. Processing of Countermeasures Signals

In signal processing, the space system should apply advanced concepts in order to manage the countermeasures used by various unmanned satellites, and catch the attack opportunities and utilize the various occasions that may possible happen. Based on concrete situations, the countermeasures system will appropriately select countermeasures. It can be expected to have artificial intelligence and nerve networking technologies. Since the space countermeasures system should be deployed in space for long periods of time, a new principle of recompilation for signal processing is required. It is allowed to have remote control input on mission software for verification and modification in order to react against the related threats in applying new countermeasures techniques.

5.3. Satellite-borne Jamming Devices

To apply jamming in a space environment, new schemes of system design are required for satellite-borne jamming devices, including new countermeasures techniques, new assemblies, and cooling schemes covering the electromagnetic frequency spectrum. Generally, a satellite-borne system stays in space for a long time, and it is unable to receive repairs and maintenance of the system, therefore new standards of reliability should be prescribed for this countermeasures equipment. Moreover, we should emphasize the limitations of satellite power supply and satellite antenna positions during design.

Space applications of countermeasures outside of satellites indicate the requirements of conducting new automated designs of dispersion of foils or flares. Thus, these two long-standing techniques can be effectively exploited in the space environment.

VI. Integration of Space Countermeasures

A space system has important military missions. The space system of the future should continuously strengthen itself by applying new emerging leading-edge technologies. With every-mounting importance of space systems, space will become a new region of military combat activities to be considered together with land, water surface (oceans), underwater, and air (the four dimensional environment). The military space system of the future will protect our military space system and weaken the enemy space system, as an important component of command and control warfare. It is expected that countermeasures technology will be a key to the space system with important functions, such as important as the function in other environments.

Due to the following factors, the development of space system countermeasures has become ever more complicated, with vast investment. The space environment itself poses a challenge, and direct combat experience is very limited, in addition to not easily determining the threat source and a weak foundation for technical development under the limitations of strict measurement and test conditions. Additionally, there is no unique planning and management department to provide development scheme and budget for space countermeasures. Thus, as the opportunity is lost, but the potential new applications (techniques) have not been utilized and developed. Therefore, the design personnel of the space systems of the future will face challenges: how to solve these problems in order to include the space countermeasures in system design and development. It will be too late to consider the problem of space countermeasures when the deployed space systems are in a dangerous environment.

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